

**U.S. DEPARTMENT OF ENERGY
NUCLEAR ENERGY RESEARCH INITIATIVE
ABSTRACT**

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Proposal No.: 99-0224

Institution: Gamma Engineering Corporation

Collaborators: Massachusetts Institute of Technology, McDermott Technologies, Materials Engineering Associates

Title: Continuous Fiber Ceramic Composite Cladding for Commercial Water Reactor Fuel

The objective of this project is to study the use of advanced ceramic materials for use as cladding for water reactor fuel elements, and to confirm, via engineering type tests, the feasibility of substituting such advanced ceramic materials for the Zircaloy cladding now in use. The ceramic materials to be developed and tested in this research program are known as oxide-based continuous fiber ceramic composites (CFCC's). DOE's Office of Industrial Technologies has sponsored work on similar composites for fossil energy applications, but no research has yet been performed on oxide based CFCC's for nuclear applications.

Oxide-based CFCC's have three main characteristics that recommend them for water reactor nuclear fuel cladding application. First, because CFCC's consist of very strong micron sized fibers in a dense ceramic matrix, they do not behave in a brittle manner. Instead they have a failure mode similar to metals (yield before failure). Second, CFCC's retain their strength to much higher temperatures (e.g. 3000 °F) as compared to metals such as zircaloy, which loose much of their strength above 1000 °F. And third, oxide-based CFCC'S (as opposed to carbide and nitride based CFCC's) remain chemically passive in high temperature steam. Thus, they do not react violently with water during a hypothetical Loss of Coolant Accident (LOCA), they do not produce heat during such an accident, and they do not produce hydrogen gas. Such characteristics, if applied to cladding in commercial water reactors, would lead to significant reductions in the consequences of LOCA's and other core overheating accidents. This could lead to improved and simplified reactor plant designs, simplified regulatory criteria, and improved public acceptance of nuclear power resulting from real reduction in residual risk.

Previous analytical studies sponsored by the USNRC and performed by Gamma in 1990, identified several ceramic composites which appear to have the required characteristics. Using internal funds, Gamma then sponsored (in 1992) fabrication development work to produce several oxide based ceramic cladding tubes having dimensions similar to LWR fuel cladding. Insufficient funds were available to continue this research into a test phase.

This NERI proposal addresses that opportunity. It aims at confirming the feasibility of providing an improved water reactor fuel element which is significantly more resistant to damage during a LOCA accident than is the current water reactor fuel element. Specifically, we propose to (1) evaluate and

select two or three specific oxide based CFCC'S which have the potential to meet LWR fuel cladding requirements, (2) fabricate L WR fuel clad test specimens from such materials using advanced CFCC fabrication techniques, (3) conduct in-pile corrosion tests on these specimens, along with standard zircaloy specimens, and (4) expose such specimens to simulated LOCA test conditions to confirm their superior performance during LOCA accident conditions.

The work will be directed and managed by Gamma Engineering Corporation, the organization which conceived and managed the initial development of this idea . The project will be done in collaboration with three subcontractors; the Advanced Materials Section of McDermott Technology Incorporated (MTI), the Nuclear Reactor Laboratory at MIT, and Materials Engineering Associates, who have conceived a unique method of conducting simulated LOCA tests on clad specimens.

If tests are successful, this new fuel element cladding could be developed by commercial fuel vendors for future advanced water reactors. The higher temperature capability of ceramic cladding, as compared to Zircaloy, and the reduction of heat and hydrogen during a low probability severe loss of coolant accident, will lead to significant reductions in the probability and consequences of accidents. This, in turn, could be reflected in improved and simplified reactor plant designs, enhanced regulatory criteria, and improved public acceptance of nuclear power resulting from the real reduction in residual risk.